INSTRUCTION MANUAL
FOR
RESISTANCE THERMOMETER BRIDGE
CATALOG NO. 72-490

SUPPLEMENT SHEETS FOR
CATALOG NO. 72-490-03

6

BIDDLE
INSTRUMENTS

JAMES G. BIDDLE CO.

INSTRUCTION MANUAL
FOR
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6

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RESISTANCE THERMOMETER BRIDGE
CATALOG NO. 72-490

1. INTRODUCTION:

Model 72-490 is a special modification of the Wheatstone Bridge, especially adapted for the precise measurement of temperature or temperature difference by the resistance thermometer method. The circuit has a double-slidewire arrangement which is mechanically linked to automatically maintain a 1:1 relation in the ratio arms. The contact resistance of one slidewire slider is in the detector circuit, while that of the second slider is in the battery circuit. Therefore, the contact resistance will not affect the accuracy of measurement.

Measurements are made by manually balancing the Resistance Thermometer Bridge. The temperature is then determined from the corresponding resistance found in the sensor's resistance-temperature table.

The instrument is designed to accommodate a wide variety of 2-lead, 3-lead, or 4-lead resistance-type transducers such as resistance thermometers, strain gages and thermistor elements.

Applications include the measurement of the boiling and freezing point of chemicals, the calibration of resistance-type transducers and recorders, and the measurement of temperature coefficients.

The top panel view of the Resistance Thermometer Bridge, which is shown in figure 1, locates and identifies the top panel components and controls.

2. SPECIFICATIONS:

A. Range:

0 to 1111.1 ohms

B. Limit of Error:

±(0.03% of reading + 0.0025 ohm)

C. Rheostat Arm:

The rheostat arm consists of three rotary switches (3, figure 1) giving steps of 10 x 100 ohms, 10 x 10 ohms and 10 x 1 ohm, plus a slidewire (9, figure 1) having a full scale resistance of 1.1 ohms. The slidewire scale is divided into 220 equal divisions of 0.005 ohm each, with major divisions marked 0, 0.05, 0.1, 0.15, etc. to 1.1. The resistance of the rheostat arm is the sum of the settings of the three step switches and the slidewire. The total range is 0 to 1111.1 ohms.

D. Ratio Arms:

The two ratio arms are approximately 130 ohms each. The double slidewire arrangement covered in section 1 automatically maintains an exact 1:1 relation in these arms.

E. Function-Selector Switch:

This is a 4-position switch (6, figure 1) that permits selection of the following functions:

(1) OFF: Electromagnetically shorts the meter, disconnects the amplifier and batteries.

(2) BRIDGE CURRENT, LOW: Sets the instrument for measurement using low-bridge current to minimize the self-heating in miniature type resistance transducers. Low-bridge current varies from approximately 0.8 ma at minimum bridge setting to 0.5 ma at maximum bridge setting.

(3) BRIDGE CURRENT, HIGH: Sets the instrument for measurement with high-bridge current to obtain maximum resolution. High-bridge current varies from approximately 10 ma at minimum bridge setting to 1 ma at maximum bridge setting.

(4) BATTERY CHECK: Sets the instrument to indicate state of charge on the measuring circuit battery directly on the meter.

F. Keys:

Separate battery and detector keys (1, 2 figure 1) are provided to permit choice of circuit closure sequence. Both keys can be locked down when desired.

G. Binding Posts:

Four, five-way type binding posts (7, figure 1) with standard 3/4" spacing are provided for connection of 2-lead, 3-lead, or 4-lead resistance-type thermometers, as well as thermometer pairs for differential measurements.

H. Detector:

The null detector consists of a ruggedized zero center meter (5, figure 1) and a solid state high gain differential amplifier which drives the meter. The characteristics are as follows:

(1) Sensitivity: 4 microvolts per division (1 division equals 1.4 millimeter).

(2) Input resistance: Greater than 500 ohms.

(3) Noise (.01 Hz to 10 Hz): Less than 1 μv peak to peak.

(4) Resolution: Sufficient to detect resistance changes of at least 0.001 ohm or 0.002% whichever is larger.

(5) Drift: Typically less than 1.0 μv per hour at constant ambient temperature after 30 minute warm-up.

(6) Response Time: Less than 1.2 seconds (0 to 90% F.S.)

(7) Overload: 2.8 V DC continuous without permanent damage.

(8) Zero Control: Provides minimum adjustment of ±100 μv to compensate for thermal and drift voltages.

(9) Sensitivity Control: Continuously adjustable from full sensitivity to approximately 10:1 reduction of sensitivity. This permits calibration of the detector meter when using the instrument as a limit bridge for production testing.

I. Meter:

2-1/2" with rugged Taut-Band suspension. The meter will withstand 50 g shock. The scale has 40 divisions and is zero center.

J. Battery Requirements:

(1) Measuring Circuit: One 1-1/2 volt No. 6 dry cell (NEDA#906). Battery life is in excess of 1500 hours (approximately 1-1/2 years at 20 hours per week).

(2) Null Detector: Two 2.8 volt mercury batteries (Mallory TR132 or NEDA 1200). Battery life is in excess of 1000 hours (approximately 1 year at 20 hours per week).

K. Enclosure:

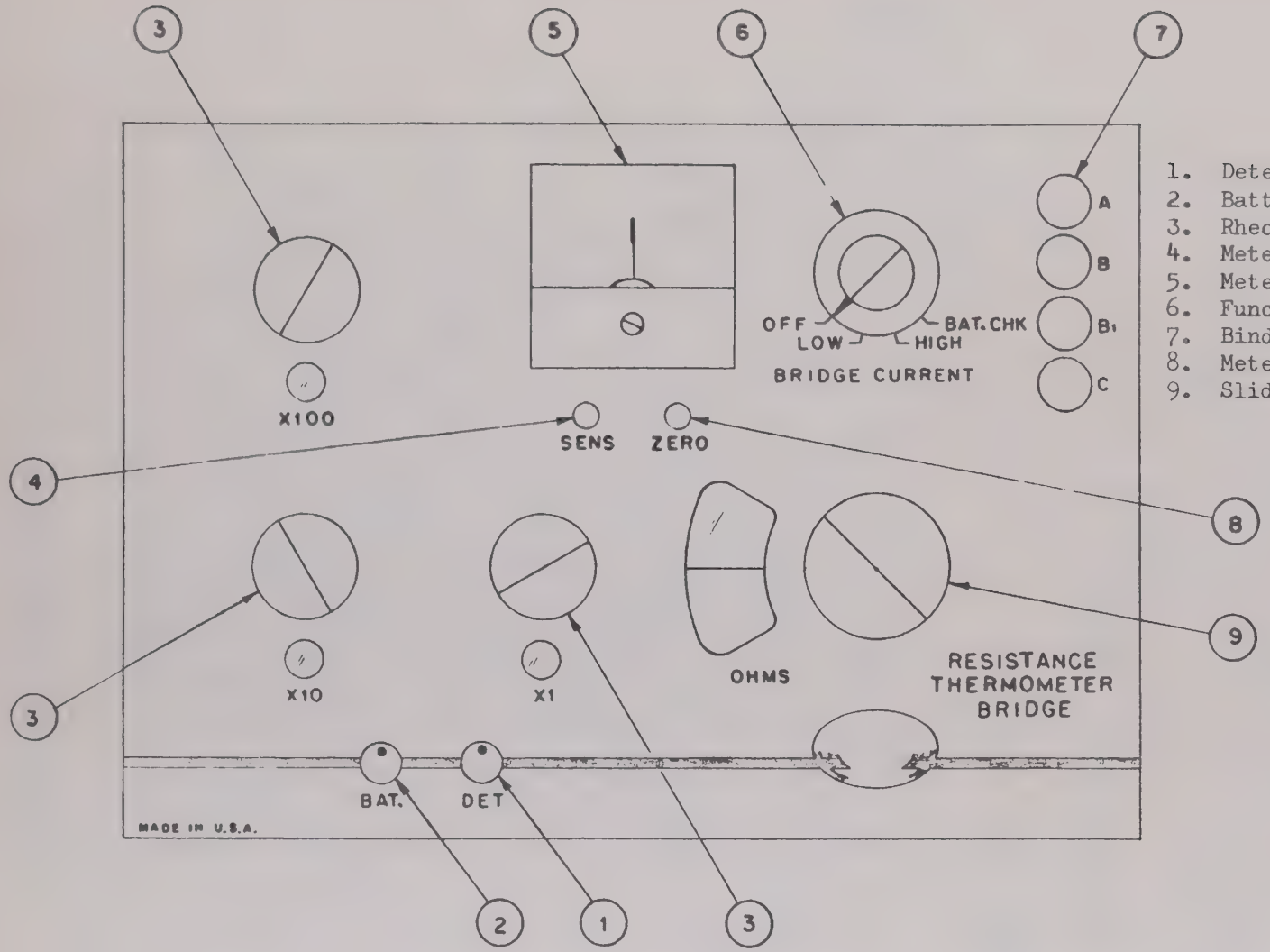
The top panel is aluminum with off-white enamel finish. The case, with lid and carrying handle, is aluminum with charcoal gray textured finish.

Dimensions: 13" x 9-1/4" x 7" high.

Weight: Approximately 12 lbs.

L. Basic Circuit Description:

The schematic diagram of the Catalog 72-490, Resistance Thermometer Bridge, is shown in figure 2. The circuit is that of a conventional Wheatstone Bridge modified by the addition of a double slidewire arrangement, which is mechanically linked to automatically maintain a 1:1 relation between the A and B ratio arms. The balancing or rheostat arm consists of three rotary switches giving steps of 10 x 100 ohms, 10 x 10 ohms and 10 x 1 ohm, plus slidewire SW 1 having a full-scale resistance of 1.1 ohms. Slidewire SW 2 maintains the 1:1 ratio arm balance. The resistance thermometer (unknown), which is connected to the A, B and C binding posts, is measured in ohms at the balanced condition of the bridge. The two 2-ohm resistors serve as calibration resistors to establish the exact 1:1 ratio between the rheostat and unknown arms, terminating respectively at the A and C binding posts.



1. Detector Key
2. Battery Key
3. Rheostat Dials
4. Meter Sensitivity Adjust
5. Meter
6. Function Selector Switch
7. Binding Posts
8. Meter Zero Adjust
9. Slidewire Dial

FIGURE 1. PANEL VIEW OF CATALOG NO. 72-490 RESISTANCE THERMOMETER BRIDGE

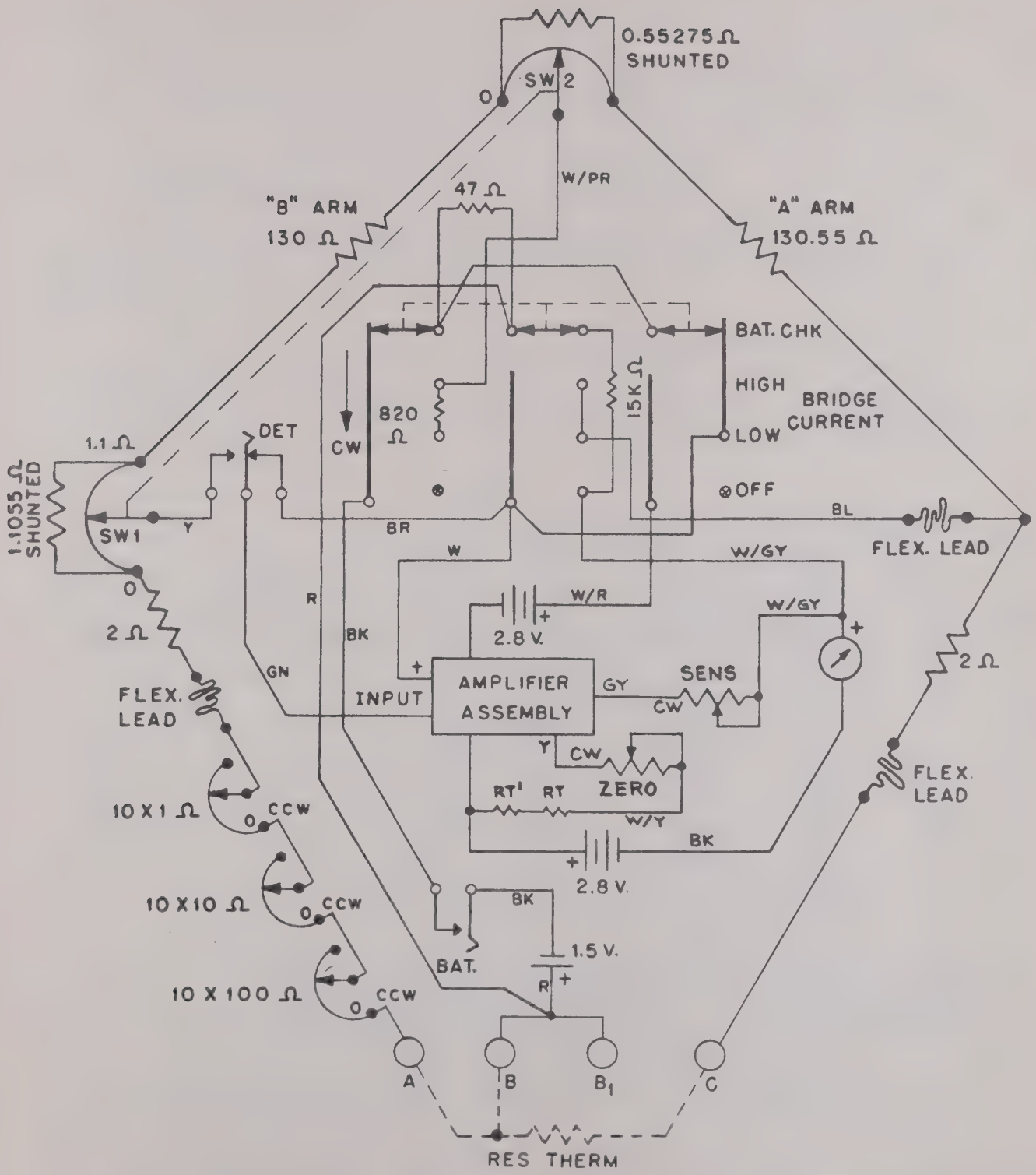


FIG. 2 SCHEMATIC DIAGRAM

3. OPERATING PROCEDURE:

A. General:

The instrument can be operated in any position and is relatively free from the effects of vibration.

B. Resistance Thermometer Current, Power Dissipation, Sensitivity, etc:

Table 1 indicates the nominal current and power dissipated by the Resistance Thermometer for both high and low bridge current for several nominal resistance values. The approximate bridge sensitivity and resistance change per °C is also listed.

The accurate measurement of resistance with a Resistance Thermometer requires that the self-heating of the sensor be limited to a value which will cause a resistance change less than a specific desired amount. In many cases the current may be so low that inadequate sensitivity will result. In this case, it will be necessary to compromise between sensitivity and sensor self-heating.

TABLE 1

NOMINAL RESISTANCE OF R.T. (OHMS)	APPROX. OHMS/°C AT NOMINAL RES. PLATINUM R.T.	HIGH-BRIDGE CURRENT			LOW-BRIDGE CURRENT		
		RES. THERM. CURRENT (MA)	RES. THERM. POWER (MW)	BRIDGE SENS. (OHMS/DIV)	RES. THERM. CURRENT (MA)	RES. THERM. POWER (MW)	BRIDGE SENS. (OHMS/DIV)
10	.04	10.5	1.1	.0004	.84	.007	.005
25	.1	9.5	2.2	.0006	.84	.018	.006
50	.2	8.2	3.4	.0008	.82	.034	.007
100	.4	6.4	4.1	.0013	.80	.064	.010
150	.6	5.3	4.2	.0020	.78	.091	.013
200	.8	4.5	4.0	.003	.76	.116	.016
500	2	2.4	2.9	.011	.67	.224	.04
1000	4	1.3	1.7	.036	.53	.281	.08

The following typical example illustrates the use of table 1:

Example:

Platinum Resistance Thermometer Value:	100 ohms at 0°C
Resistance Temperature Coefficient:	0.00392 Ohms/Ohm/°C
Self-Heating Constant:	20 milliwatts/°C
Accuracy Desired (Resistance Change):	0.05°C at 0°C

Since the desired accuracy is 0.05°C, the equivalent permissible self-heating must be limited to:

$$\frac{20\ MW}{1°C} \times 0.05°C = 1MW$$

From table 1 it can be seen that the high-bridge current at 100 ohms will cause 4.1 MW of self-heating in the resistance thermometer (equivalent to .2°C). This is in excess of the value desired.

The low-bridge current (.064 MW of self-heating) must be used to obtain the desired accuracy. The self-heating error in this case will be:

$$\frac{1°C}{20\ MW} \times .064\ MW = .0032°C$$

The resolution in °C per division of meter deflection for the low-bridge current will be:

$$\frac{1°C}{.4\ Ohm} \times \frac{.010\ Ohm}{Div} = .025°C/Div$$

C. Meter Zero Adjustment

(1) Rotate the Function Selector Switch to the OFF position and adjust the meter to the mechanical "0" of its scale, if required, by rotating the slotted head screw on the meter cover.

(2) Rotate the Function Selector Switch to the HIGH or LOW BRIDGE CURRENT position, the SENS control to the extreme clockwise position (maximum sensitivity), then rotate the ZERO control until the meter pointer balances at "0".

NOTE: When the pointer cannot be adjusted to "0" of its scale, or the detector sensitivity is significantly less than that stated in Table 1, replace the amplifier batteries.

D. Battery Check

Check the state of charge on the measuring circuit battery prior to making measurements. Proceed as follows:

(1) Adjust the meter to the mechanical "0" of its scale, if required, as described in section 3C.

(2) Rotate the Function Selector Switch to the BAT. CHK. position.

(3) Depress the BAT. key and note the meter deflection. A new battery (nominal 1.5 volts) will cause the meter pointer to deflect to the right at least full scale. If the meter pointer deflects less than 14 divisions to the right (equivalent to 1.05 volts) the measuring circuit battery should be replaced as this is the approximate service life end point.

NOTE: (a) Do not depress the DET key.

(b) The SENS control is not in the circuit.

E. Measuring a Temperature

(1) Connect the Resistance Thermometer to the bridge. Refer to section 4.

(2) Adjust the meter to "0" of its scale as described in section 3C.

(3) Rotate the Function Selector Switch to the HIGH or LOW BRIDGE CURRENT position as required. Refer to Table 1.

(4) Rotate the rheostat dials to the nominal resistance of the Resistance Thermometer.

(5) Depress the BAT. key, then the DET key and note the meter deflection. If the deflection is to the right, the bridge dial setting is too high; if to the left, too low. Adjust the bridge dials for null meter deflection, starting with the highest value dial.

(6) Lock down the DET key and readjust the slidewire, if necessary, for null meter deflection while depressing and releasing the BAT. key.

NOTE: (a) Adjust the SENS control, if desired, to obtain optimum detector sensitivity or to calibrate the meter deflection in terms of ohms or °C deviation from nominal. Clockwise rotation of the SENS control increases sensitivity; counterclockwise rotation decreases sensitivity. At minimum sensitivity the detector response is linear for a deflection of ±5 meter divisions, but is reduced non-linearily beyond this point as the input voltage increases. At maximum sensitivity the detector response is linear for the entire ±20 meter divisions.

(b) For precise resistance measurements, with minimum thermal emf errors, it is recommended the meter be adjusted to "0" of its scale when connected directly across the bridge circuit under measurement conditions, approximate bridge balance, full detector sensitivity, with the DET key depressed, and with the BAT key in the open position.

(7) Read the value of measured resistance in ohms, by taking the sum of the step switches and slidewire reading.

(8) Find the temperature from the corresponding resistance, using the Resistance Thermometer Sensor's resistance-temperature table.

4. APPLICATION AND CONNECTIONS FOR VARIOUS RESISTANCE THERMOMETERS:

A. Two-Lead Resistance Thermometer:

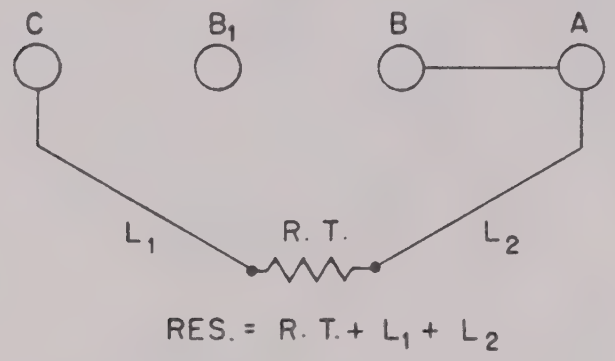


FIGURE 3.

(1) Connect the Resistance Thermometer leads to binding posts A and C as shown.

(2) Short binding posts A and B with a piece of heavy copper wire (#10 or #12 AWG).

(3) Take a reading as outlined in section 3. The measured resistance includes the L_1 and L_2 lead resistance.

B. Three-Lead Resistance Thermometer:

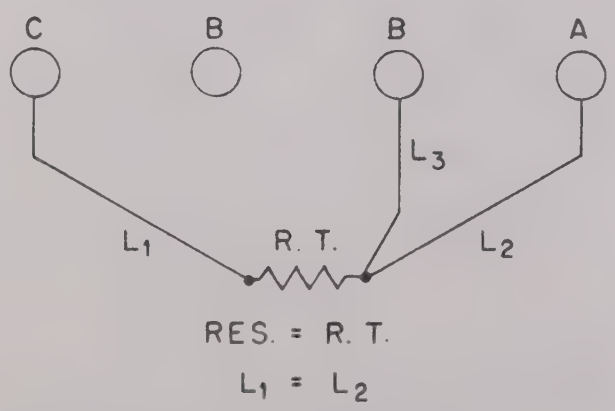


FIGURE 4.

(1) Connect the Resistance Thermometer leads to binding posts A, B and C as shown.

(2) Take a reading as outlined in section 3. The measured resistance is that of the Resistance Thermometer providing leads L_1 and L_2 are equal.

C. Four-Lead Resistance Thermometer:

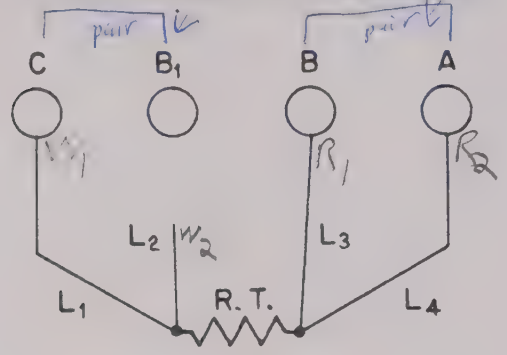


FIGURE 5A

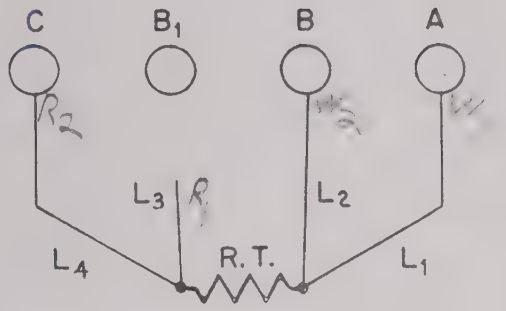


FIGURE 5B

R.T. Normal Resistance (R_N)

$L_1 = L_4$

R_N = R.T.

R.T. Reverse Resistance (R_R)

$L_1 = L_4$

R_R = R.T.

$$\text{RES.} = \frac{R_N + R_R}{2}$$

(1) Connect the Resistance Thermometer leads to binding posts A, B, and C as shown in figure 5A.

NOTE: Four-Lead Resistance Thermometer leads may be marked C, c, t, and T. Leads C and T are the "current" or "main" leads, and c and t are the "potential" leads. Connect the "current" leads to the A and C binding posts of the bridge.

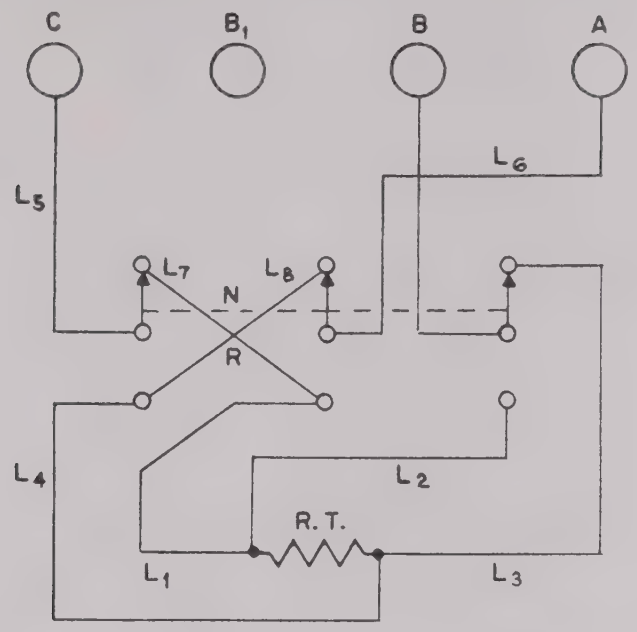
(2) Take a reading as outlined in section 3.

(3) Reverse the leads as shown in figure 5B and repeat the reading.

(4) The resistance value of R.T., independent of error due to lead resistance is:

$$\text{RES.} = \frac{R_N + R_R}{2}$$

(5) A convenient method for switching the four-lead Resistance Thermometer is shown in figure 6. A 3-pole, double-throw switch, with low-contact resistance should be used, preferably a mercury switch. It is important that the leads be equal as shown.



$L_1 = L_4$

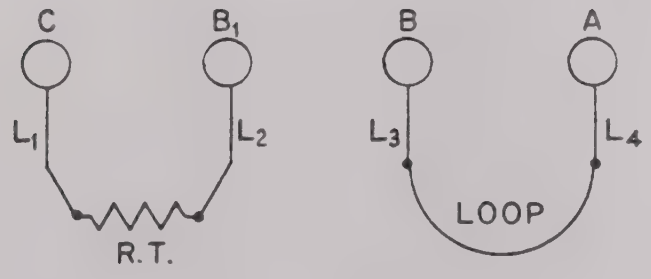
$L_5 = L_6$

$L_7 = L_8$

REVERSING SWITCH FOR FOUR-LEAD RESISTANCE THERMOMETER

FIGURE 6.

D. Four-Lead Loop-Type Resistance Thermometer:



$L_1 + L_2 = L_3 + L_4$

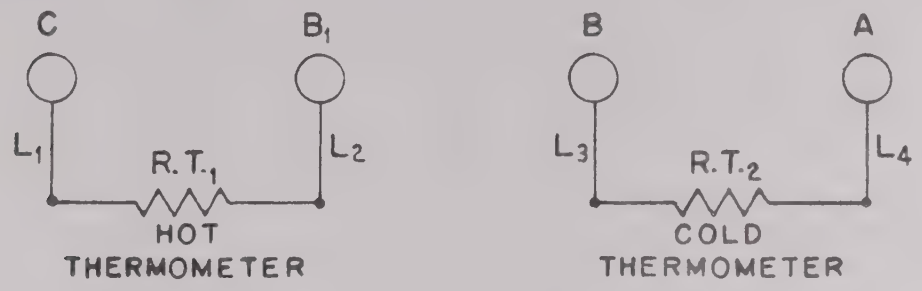
RES. = R.T.

FIGURE 7.

(1) Connect the four-lead loop-type Resistance Thermometer to the bridge as shown in figure 7. It is important that the leads be equal as shown.

(2) Take a reading as outlined in section 3. The measured resistance (RES) is the exact resistance of the Resistance Thermometer (R.T.)

E. Temperature Difference Using Two, Two-Lead Resistance Thermometers:



$L_1 + L_2 = L_3 + L_4$

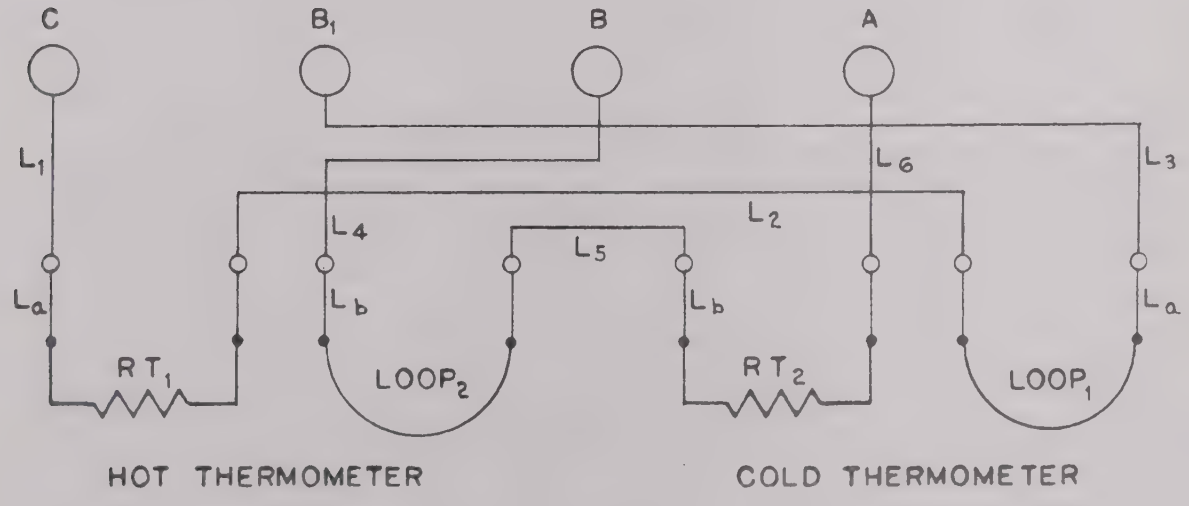
$RES. = RT_1 - RT_2$

FIGURE 8.

(1) Connect the Resistance Thermometers to the bridge as shown in figure 8. It is important that the leads be equal as shown.

(2) Take a reading as outlined in section 3. The measured resistance (RES) is the difference between the hot and cold thermometers ($RT_1 - RT_2$).

F. Temperature Difference Using Two, Four-Lead Loop-Type Resistance Thermometers:



$L_1 + L_2 + L_3 + L_a = L_4 + L_5 + L_6 + L_b$

$RES. = RT_1 - RT_2$

FIGURE 9.

(1) Connect the loop-type Resistance Thermometers to the bridge as shown in figure 9. It is important that the total lead resistance associated with each particular loop be equal as shown. Resistance L_a represents the internal lead

resistance of RT_1 and $LOOP_1$; while L_b represents the resistance of RT_2 and $LOOP_2$. The Resistance Thermometers must be equal in resistance, and the LOOP of the hot thermometer placed in series with the cold thermometer, and vice versa.

NOTE: This method is used where there is a possibility of a change in the resistance of the leads, due to the temperature difference, which could affect the balance.

(2) Take a reading as outlined in section 3. The measured resistance (RES) is the difference between the hot and cold thermometers (RT_1 - RT_2).

5. MAINTENANCE:

A. General:

With normal use the only maintenance required will be replacement of the batteries and an occasional cleaning and lubrication of the slidewire after long periods of disuse. Instruments having only periodic use should have their measuring dials rotated several times over their full travel previous to making a measurement.

B. Removal of Bridge from Case:

(1) Remove the six panel screws.

(2) Carefully lift the instrument from the case and disconnect the two-lead cable at the battery.

(3) Replace the bridge in the case by following the reverse procedure described above.

C. Battery Replacement:

Replace the measuring circuit battery when the meter pointer deflects less than 14 divisions when checking the battery as described in section 3D. Replace the null detector batteries when the meter pointer cannot be adjusted to "0" as described in section 3C. The battery compartment is in the bottom of the instrument. Remove the panel assembly from the case as described in section 5B.

The battery requirements and their connections are as follows:

Measuring Circuit: One 1½ volt, #6 dry Cell (NEDA #906)
Red lead connection to positive (+) terminal
Black lead connection to negative (-) terminal

Null Detector Circuit: Two 2.8 volt mercury batteries (Mallory TR132 or NEDA 1200)
Proper polarity marked on battery holders.

NOTE: Incorrect installation of the null detector batteries, defective batteries, or failure to make contact with the battery holders will cause the meter pointer to deflect violently off scale or result in failure of the pointer to move when the ZERO control is rotated with the Function Selector Switch in the HIGH or LOW BRIDGE CURRENT position.

D. Slidewire:

(1) The need for slidewire cleaning is indicated by erratic deflection of the meter, when smooth slidewire rotation is applied, while at or near meter null balance when measuring with the DET key depressed.

(2) Remove the bridge from the case as described in section 5B.

(3) Clean the slidewire surface by rubbing briskly with a soft cloth moistened with Naphtha, Chloroethylene, Benzene, Alcohol or other volatile petroleum solvent. Dry with soft cloth. Lubricate by rubbing lightly with a soft cloth sparingly impregnated with petroleum jelly or white vaseline.

(4) On severly oxidized slidewires, not cleanable by step 3 above, polish gently with crocus cloth uniformly over the full length of the slidewire, then repeat step 3 above.

(5) Replace the bridge in the case as described in section 5B.

E. Push Keys:

Failure of the push keys to make contact will be indicated by the failure of the meter pointer to deflect when an unbalance is known to exist.

Key contacts may be cleaned by inserting a thin strip of bond paper or business card between the contacts and applying pressure to the contacts by depressing or releasing the key button as required while withdrawing the paper. Repeat three or four times, or as necessary.

F. Amplifier Assembly:

No maintenance of the amplifier assembly is required under normal use, due to its solid-state construction, other than battery replacement which is described in section 5C.

G. Meter Replacement:

Meter failure usually occurs by suspension breakage due to a severe shock. It is indicated by the failure of the meter pointer to deflect when an unbalance is known to exist. To detect, rotate the Function Selector Switch to the OFF position, then impart a slight rotational motion to the instrument in a plane parallel to the panel. If the suspension is broken, the pointer will not swing.

To replace the meter, remove the panel assembly from the case as described in section 5B and proceed as follows:

(1) Disconnect the wires from the meter terminals.

(2) Remove the 4 nuts holding the meter in place and lift the meter out of the panel.

(3) Remove the piece of wire (short) from the terminals of the new meter and install meter following the reverse procedure described above.

NOTE: Connect White/Blue wire to positive (+) meter terminal.

Connect Purple wire to negative (-) meter terminal.

H. Measuring Circuit:

Calibration and repair of the measuring circuit should only be attempted in the laboratory under controlled conditions. For those operations not described above, or the replacement of parts not listed below (section 6), it is recommended that the instrument be returned to the factory.

6. FIELD REPLACEABLE PARTS LIST:

PART NO.	QUANTITY/INSTRUMENT	DESCRIPTION
11883	1	Meter
11166-2	4	Binding Posts (Superior #DF31BC)
7184-6	1	Knob, slidewire
7184	1	Knob, function switch (Raytheon #90-3-2) with pointer.
7184-1	3	Knob, X100, X10, X1 rotary switches (Raytheon #125-2-2).
11868	2	Knob, zero, sens control (Stockwell Rubber Co. #LC9250-1).
11357-3	2	Push key, Bat. and Det.
11212	1	Battery, 1½ volts, #6 dry cell (NEDA #906).
11892	2	Battery, 2.8 volt, mercury (Mallory TR132, TR132R or NEDA #1200).

For replacement of parts not listed, return to factory.

Resistance Thermometer Bridge
Cat. No. 72-490-03

SUPPLEMENT SHEETS TO 72-490 INSTRUCTION MANUAL

Page 3 - J, (2) Null Detector:

Two 9V zinc-carbon batteries (Eveready #266, NEDA-1605). Battery life is in excess of 1200 hours. (Approximately 14 months at 20 hours per week). Located in bottom of case, secured by bracket.

K, Enclosure:

Weight: Approximately 13 pounds.

Page 5 - Figure 2

Refer to schematic diagram 72-490-03. (Sheet 2)

Page 13 - C Null Detector Circuit:

Two 9V zinc-carbon batteries (Eveready #266, NEDA-1605). Connected by snap-on terminals.

Page 15 -6 Field Replacable Parts List:

Part No. 11892 (2) replaced by part No. 13045 (2).

Description: Battery 9V, Zinc-carbon.
Eveready #266, NEDA-1605.

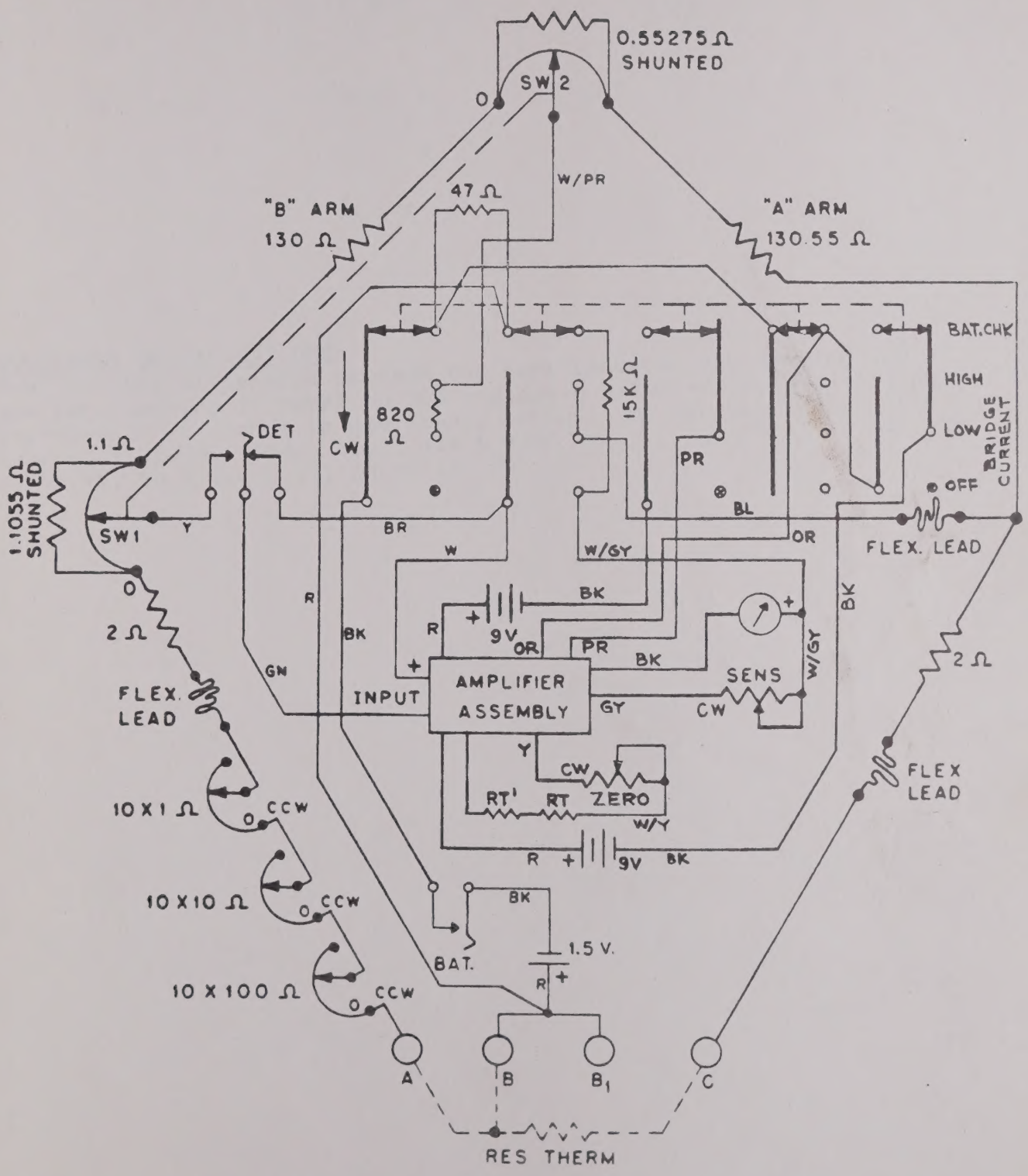


FIG. 2 SCHEMATIC DIAGRAM

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